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Interactive Maintenance Assistant Job Aids that Provide System Visualization

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HFE TAG
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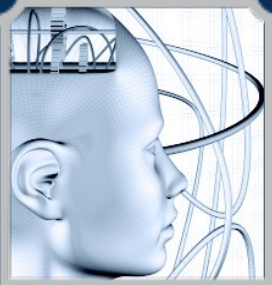

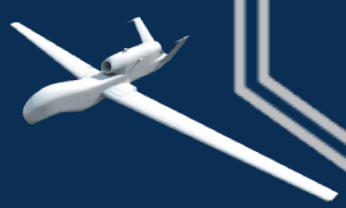

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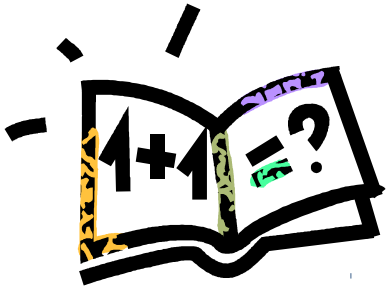
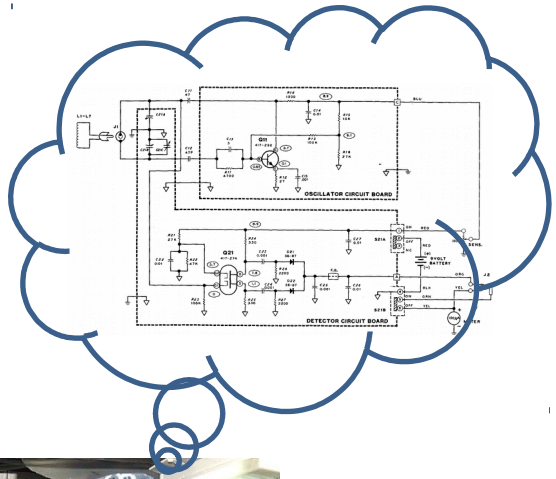
Introduction

- How to improve job performance with performance aids





Why this may be interesting to you

- Improving performance in complex jobs
  - Reduce errors / Safety
- Measurement of performance
- Eliciting and representing maintainers' mental models
- Relationship between Performance Aids and Training
- Use of tablets for bringing information to technicians
- See how you insights and wisdom can be applied to the project

Agenda

- The challenge that IMA addresses
- Context
- Approach
- Current State
- Next Steps

Challenge IMA addresses

- Maintenance personnel - a growing problem area
  - Technicians do not stay in the field long
  - Need to become experts quickly to attend to complex issues
  - Significant time gap between school and actual work on ship
  - Need to leverage the knowledge of experts

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Challenge IMA addresses

- Other operational goals
  - Reduce costs
    - Move some training from schoolhouse to ship
    - Reduce downtime of equipment (currently 50%!)
  - Improve (or at least maintain) readiness
  - Help technicians perform well with complex faults (vs. classroom faults)

Agenda

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Context: IMA—Operational Navy Goals

- Use tablets to assist performance of Navy technicians in maintaining equipment.

ONR Goals

- ONR research interests:
  - Creation of job aids that can help technicians diagnose complex faults
    - By increasing their conceptual understanding of the procedures and the operation of the equipment
  - Leverage expert knowledge and other available information to develop job aids that will help technicians do a better job
- Transition goals:
  - Benefit the Navy
  - Improve the performance of technicians through the use of job aids that help technicians develop expert-like mental models

Our Research Program

- Develop job aids for technicians to support human performance with complex systems
  - Use tablet-based job aids for maintenance procedures
    - Support conceptual understanding of procedures and equipment when appropriate
    - More than just electronic procedures!
  - Evidence-based decisions on design and deployment of performance supports
    - Navy will share available data sources for answering research questions

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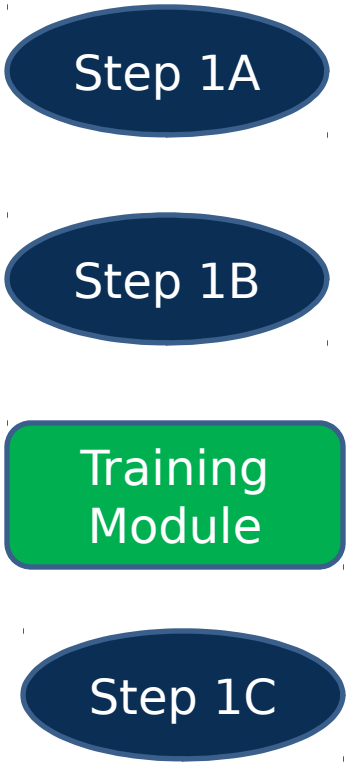
Previous Research by Intelligent Automation

- Adaptive Visualization Training (AVT) helped Fire Control technicians improve knowledge of equipment operation
- AVT taught mental models to technicians
  - Context of knowledge application:
    - Maintenance technicians always follow prescribed procedures
    - Expert technicians used “pictures in their heads”
      - To understand purpose of procedure (intent)
      - To understand how procedures use the results of tests (interpret)
    - Consulted with expert learning scientists
      - Present instruction within situated contexts
      - Lead students through interactions
      - Adapt to trainee needs
      - Show multiple perspectives

Training flow of AVT

- On Navy simulation, student executes steps specified by maintenance procedures.
- Trainees read procedures, execute steps on simulation

- As trainee executes steps, occasionally training interjects a training module.
- In a training module, training asks trainee a question.
- In constructing answers, trainees construct their visualization.

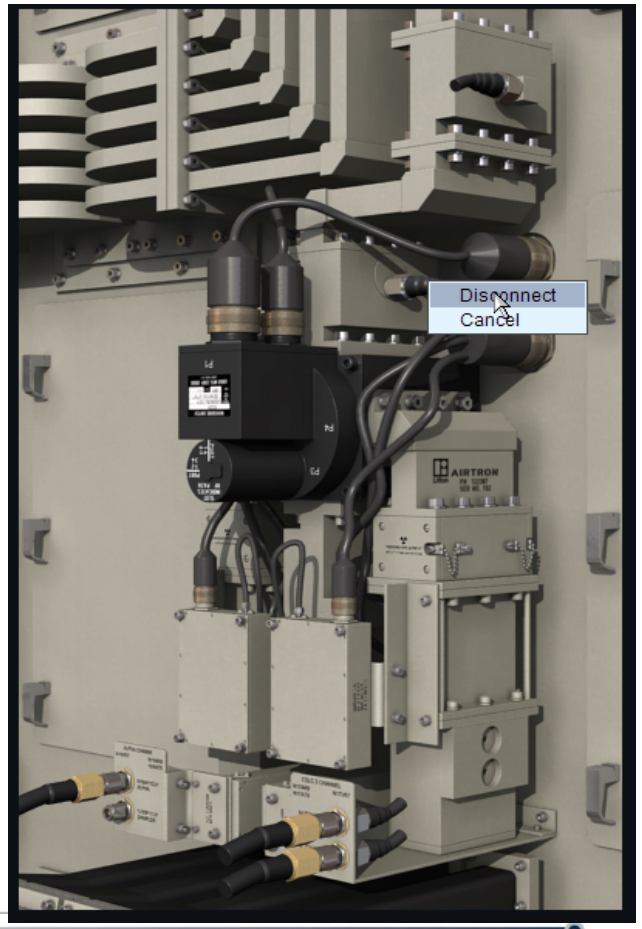


Students perform procedures on simulation

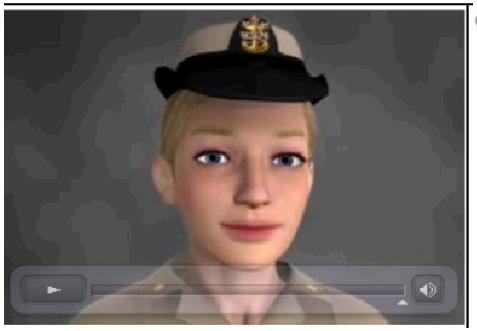
- Technicians follow step-by-step procedures on the job
  - On Navy simulation, trainees execute steps specified by maintenance procedure:

a. In INSTRUMENT STATE of analyzer front panel, press PRESET. Perform the following for array being aligned. From softkey menu, press SEQUENCE (2,3,4,5), (FORE,AFT,PORT,STBD).
b. Follow prompt on screen. Connect black cable to port 1.
c. Press CONTINUE SEQUENCE (f1).
d. Follow prompt on screen. Connect blue cable to port 2.
e. Press CONTINUE SEQUENCE (f1).

NOTE 10 : Refer to figure 2 for test equipment setup for the following steps. Cable B should be laid out on deck so that



AVT interactive training module

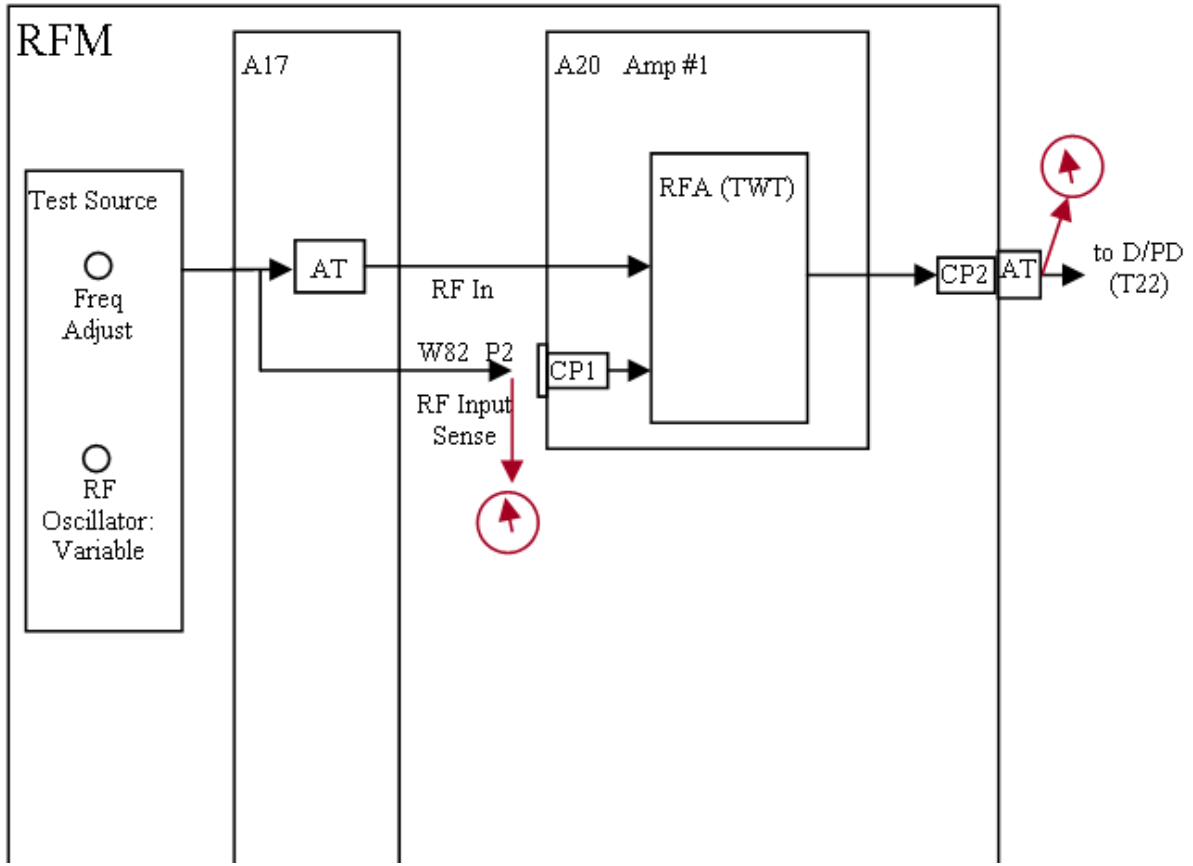


Question: Show hin

Why do we seek frequency with minimum power when measuring Test Source RF at W82P2?

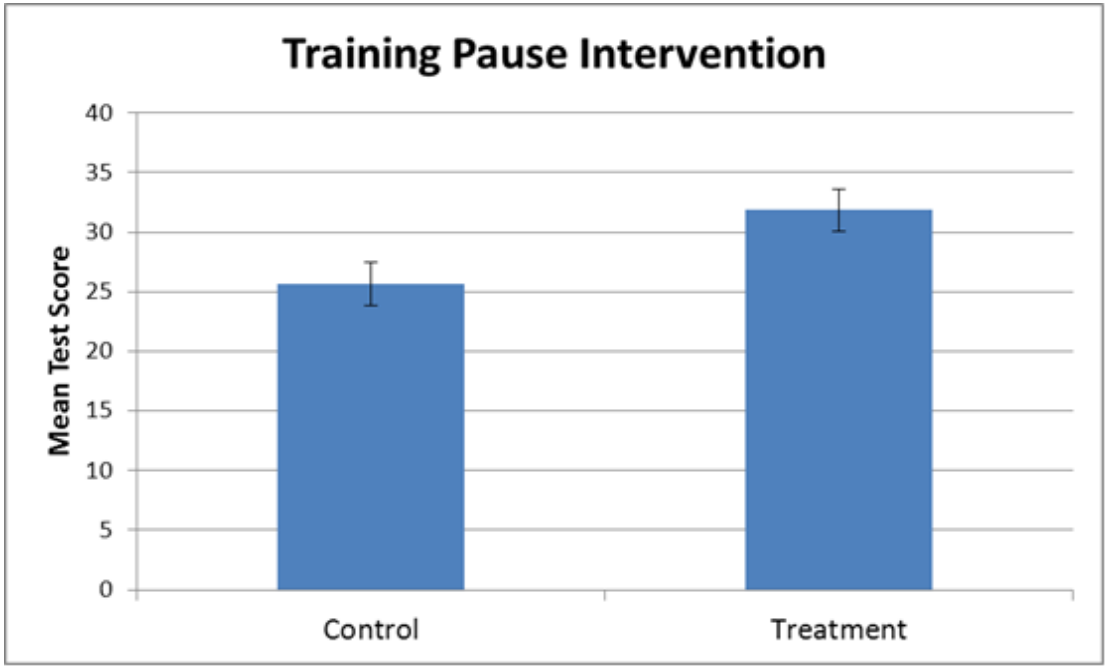
Answer:

This procedure seeks frequency with lowest power in order to



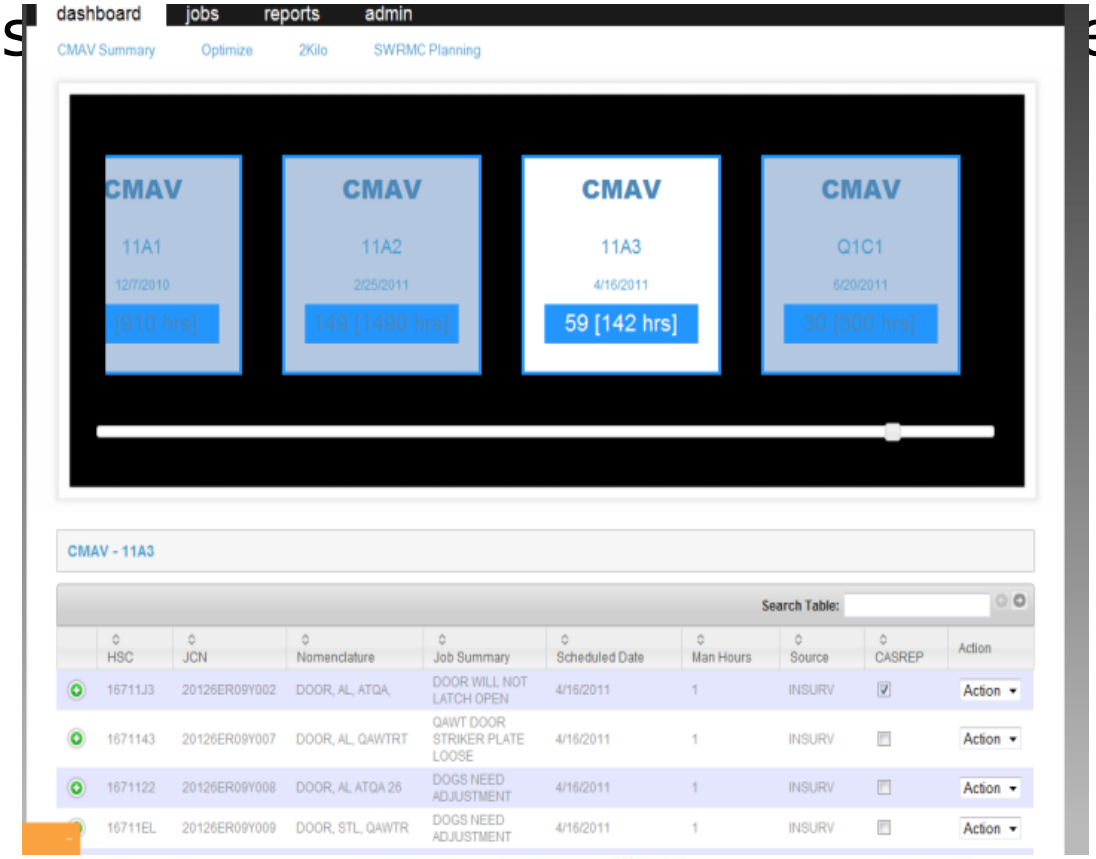
Adaptive Visualization Training (AVT) Results

- Developed for NAVSEA training using existing simulator for SPY-1A and 1D
- Results: 24 % better post-test performance with ~ 1 hour additional (total) training time added to 12-day program, t-test is significant



Integrate IMA with Navy Tablet to be deployed

- Reliability Engineer Data Integration (REDI) appears to be the tablet system Navy will deploy for maintenance technicians
- IMA is [redacted] egration with REDI



Agenda

- The challenge that IMA addresses
- Context
- **Approach**
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Apply knowledge from AVT

- Transform training content from AVT to create Job Aids
  - Technicians work on real equipment
  - Technicians follow procedural steps from tablet
  - Occasionally tablet presents an advance organizer instead of next step

- Measure effectiveness of Job Aids
  - Technicians perform procedures on equipment mock-up at schoolhouse
  - Solve real-world faults (from maintenance records on ship)

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Transform AVT Training Content to Job Aids

Training content:

- Trainees reflect on what they had done
  - Trainees need to stop and think about their actions in a broader context

Job Aid content for mental models

- Advance Organizer provide context for actions technicians will take
  - Technicians should be interrupted minimally as they solve real problems

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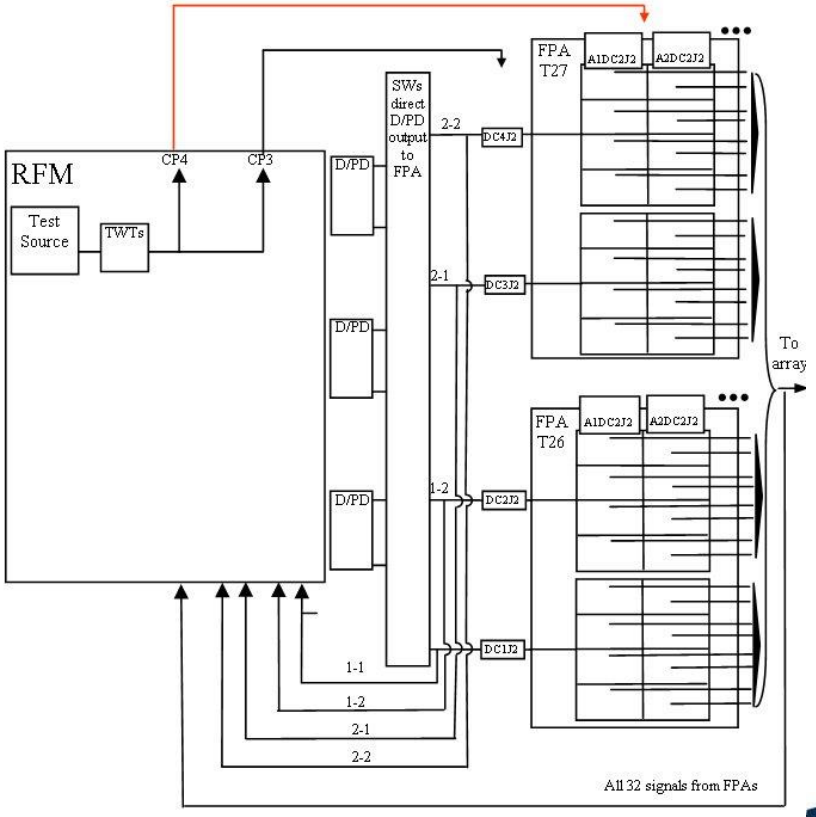
Difference of training & job aid content

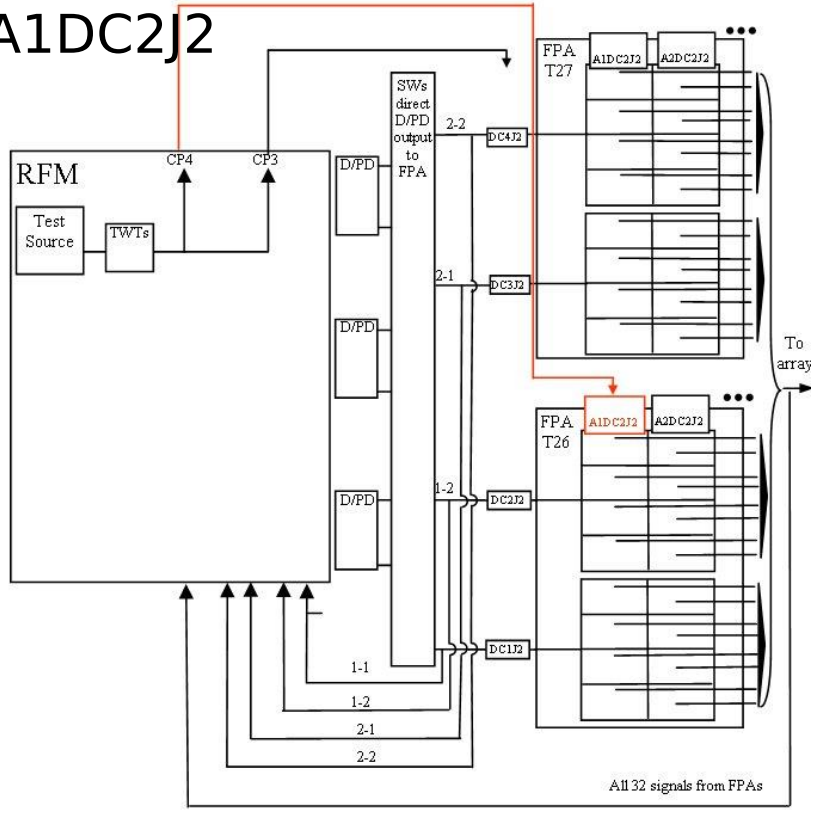
- Training

A connection has been made from the RFM CP4. Where is it connected? Click on a point in



- Job Aid

Step 2 sets up stimulus cables to FPA from RFM. Connect cable from CP4 to T26 A1DC2J2



Transforming “Fill in the Blank” Training to Job Aid

Training

After phase aligning and recording power for all 32 channels, what was accomplished?

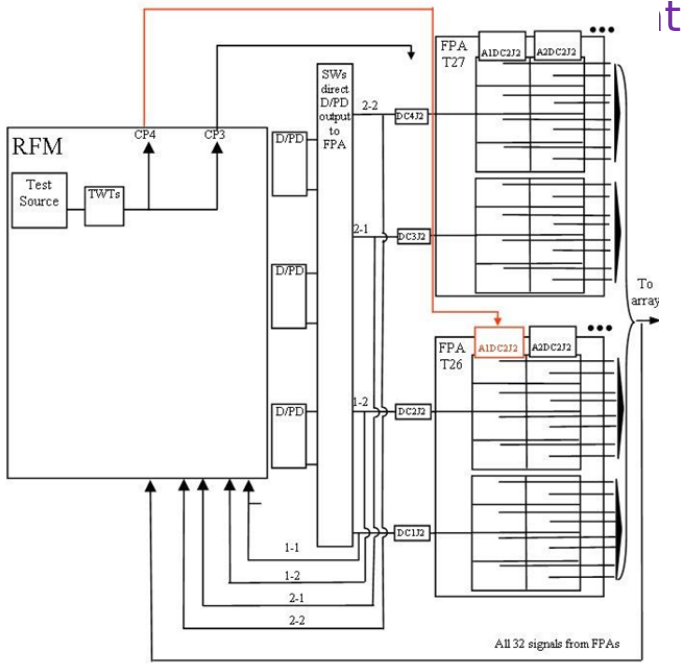
Answer: Phase aligning all 32 channels sets the sample paths measured to _____.

Alignment of sample paths is used for ____. Recording power is used for ____.

Phase aligning all 32 channels sets the sample paths to the same effective length. Alignment of sample paths is used for later checks, and monitoring phase during tactical operations. Recording power from all 32 channels is used in later steps for adjusting the power to specification.

Job Aid

All 32 channels from FPA are measured for (1) phase alignment, so the sample paths are all the same length, and their phase can be monitored during tactical operations. (2) Power is measured for use in later steps for a tion.



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Placement of AVT Training Modules

- Training modules placed at end of a procedural segment

j. At RDT, type M. (At TCD, select Modify and configure stim as follows:)
k. Set word 13 ARR = 1 via PFK 8. (Set word 13 ARR to 1. Select Quit button in the ffedit window.)
l. Apply stim repetitively via PFK 3. (Select Apply button in the Radar Stimulus window for repetitive stim application)
m. Observe power meter and record level on figure 1 under NOISE, NORMAL for APR = 1.
n. At RDT, type M. (At the TCD, Select Stop within the Radar Stimulus window.)
o. Set word 13 APR = 0 via PFK 8. (At TCD, select Modify and configure stim as follows: Set WD 13 ARR to 1)
p. Set word 29 MS1 = 0 and MA1 = 06 via PFK 8. (Set WD 29 MS1 to 0 and MA1 to 6. Select Quit button in the ffedit window.)
q. Set variable attenuator dials:
(1) 10 dB to 60
(2) 1 dB to 2
r. Apply stim repetitively via PFK 3. (Select Apply button in the Radar Stimulus window for repetitive stim application.)
s. Observe power meter and record level on figure 2 under SIGNAL, NORMAL for ARR = 0.
t. At RDT, type M. (Select Stop within the Radar Stimulus window.)
u. Set word 13 ARR = 1 via PFK 8. (Set WD 13 ARR to 1. Select Quit button in the ffedit window.)
v. Apply stim repetitively via PFK 3. (Select Apply button in the Radar Stimulus window for repetitive stim application.)
w. Observe power meter and record level on figure 2 under SIGNAL, NORMAL for ARR = 1.
x. Using format shown in figure 2, calculate NORMAL AVERAGE NOISE and NORMAL AVERAGE SIGNAL; record. Algebraically, add ARR = 1 value to ARR = 0 value and divide by 2.
y. Calculate difference between NORMAL AVE SIGNAL and NORMAL AVERAGE NOISE values and record value under mCa AVE. Use absolute values of both averages.
z. Algebraically, add mCa AVE to SIGNAL, NORMAL value for ARR = 0 and ARR = 1; record under REF NOISE FLOOR in figure 3.

Training Module

Training Module

Placement of IMA Advance Organizers

- Present content as a preview of the steps trainees will take

j. At RDT, type M. (At TCD, select Modify and configure stim as follows:)
k. Set word 13 ARR = 1 via PFK 8. (Set word 13 ARR to 1. Select Quit button in the ffedit window.)
l. Apply stim repetitively via PFK 3. (Select Apply button in the Radar Stimulus window for repetitive stim application)
m. Observe power meter and record level on figure 1 under NOISE, NORMAL for APR = 1.
n. At RDT, type M. (At the TCD, Select Stop within the Radar Stimulus window.)
o. Set word 13 APR = 0 via PFK 8. (At TCD, select Modify and configure stim as follows: Set WD 13 ARR to 1)
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q. Set variable attenuator dials:
(1) 10 dB to 60
(2) 1 dB to 2
r. Apply stim repetitively via PFK 3. (Select Apply button in the Radar Stimulus window for repetitive stim application.)
s. Observe power meter and record level on figure 2 under SIGNAL, NORMAL for ARR = 0.
t. At RDT, type M. (Select Stop within the Radar Stimulus window.)
u. Set word 13 ARR = 1 via PFK 8. (Set WD 13 ARR to 1. Select Quit button in the ffedit window.)
v. Apply stim repetitively via PFK 3. (Select Apply button in the Radar Stimulus window for repetitive stim application.)
w. Observe power meter and record level on figure 2 under SIGNAL, NORMAL for ARR = 1.
x. Using format shown in figure 2, calculate NORMAL AVERAGE NOISE and NORMAL AVERAGE SIGNAL; record. Algebraically, add ARR = 1 value to ARR = 0 value and divide by 2.
y. Calculate difference between NORMAL AVE SIGNAL and NORMAL AVERAGE NOISE values and record value under mCa AVE. Use absolute values of both averages.
z. Algebraically, add mCa AVE to SIGNAL, NORMAL value for ARR = 0 and ARR = 1; record under REF NOISE FLOOR in figure 3.

Segment Preview

Segment Preview

Summary of Transforming Training to Job Aids

- Content is transformed from a question to a statement
- Content presented as an advance organizer rather than reflection

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Agenda

- The challenge that IMA addresses
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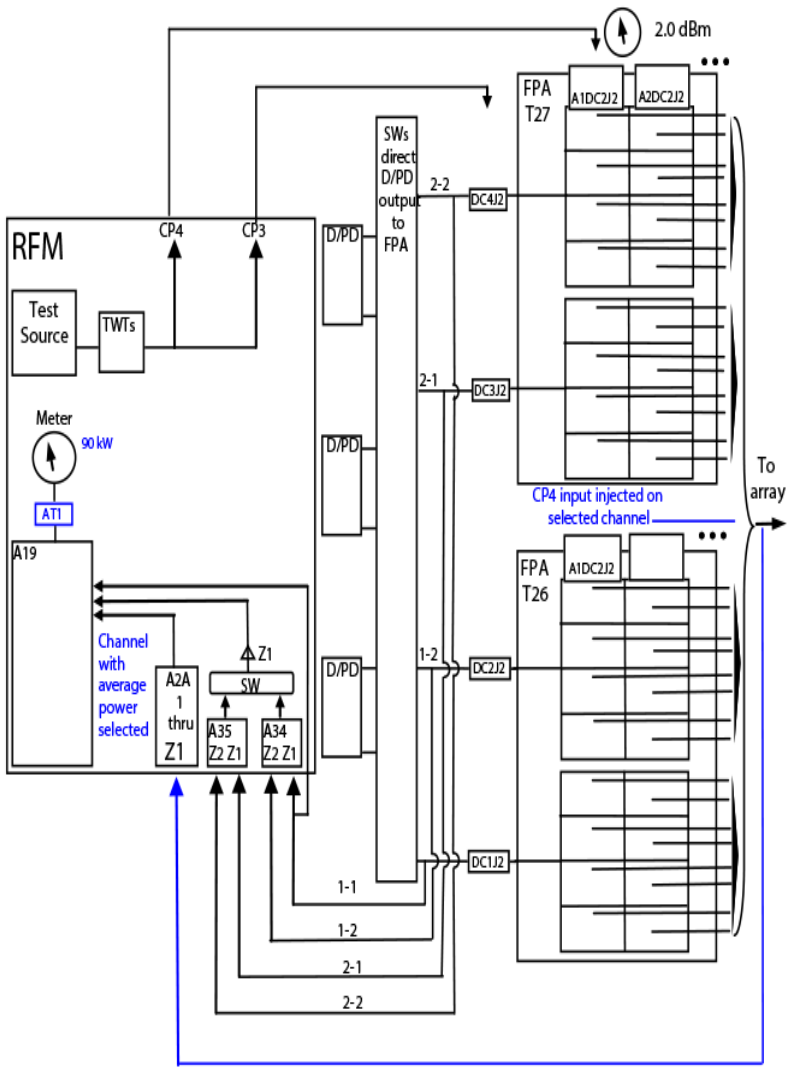
Current State

- Some maintenance procedures have been created
- Pilot studies and Modifications

Screen shot from test tablet

You will select a channel that is the average (of functioning channels), and adjust an Attenuator so the power meter reads 90kW. The average channel is calibrated with a 2dBm input to the channel. The attenuator is adjusted so the average reads 90kW for interpreting measured power during operation. Next

Diagram | MRC Figure

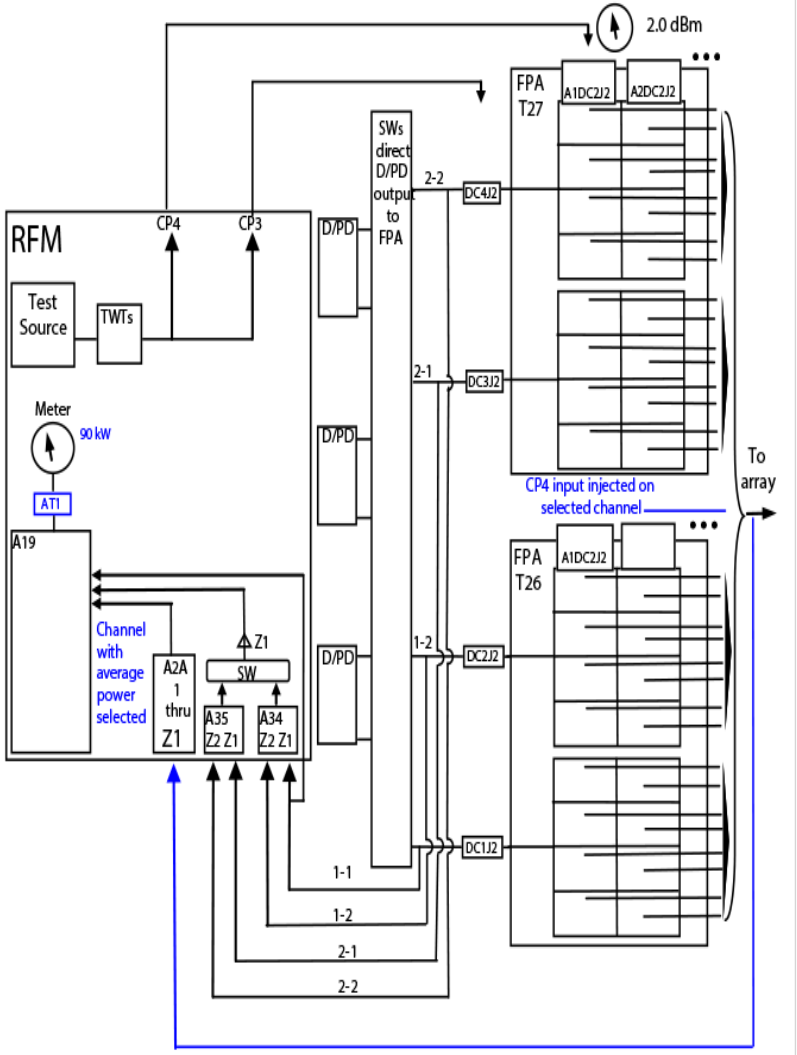


Screen shot from test tablet

- aj. Using 32 power readings recorded on data sheet in table 1, calculate Initial Mean Power Reading by adding all 32 recorded readings and dividing their sum by 32. Record on data sheet in table 1.
- ak. Compare 32 channel readings with Initial Mean Power Reading recorded in step 1.aj. and compute Final Mean Power Reading as follows:
  - (1) If any channel differs from mean by more than 15%, then that channel data is faulty - calculate Final Mean Power Reading using only those channels that differ from mean by less than or equal to 15%. For example: If recorded power reading for channel 32 varies from Initial Mean Power Reading by more than 150 o. then add channels I through 31 and divide their sum by 31. Record Final Mean Power Reading on data sheet in table 1.
  - (2) If no channel differs from Initial Mean Power Reading by more than 1500, then record Initial Mean Power Reading as Final Mean Power Reading on data sheet in table 1.
- al. Select 1 channel whose recorded power reading is closest to Final Mean Power Reading obtained in step 1.ak. Record channel number on Data Sheet in table 1.
- am. Disconnect 25-foot cable from FPA T27 (T29) A16DC2J2 and reconnect A16W3 to AI6DC2J2. Close and fasten FPA CFA access door.
- an. Using a type N adapter, connect power meter to 25-foot cable disconnected in step 1.am.
- ao. At REM A15 Maintenance Control Panel, set TRIGGER GENERATOR TRIGGER-MODE to FREE RUN.
- ap. If necessary. adjust variable attenuator for a power meter reading of 2.0 dBm.
- aq. At REM, Al 5 Maintenance Control panel, set TRIGGER GENERATOR TRIGGER-MODE to SINGLE PULSE.
- ar. Disconnect type N adapter and power meter from 25-foot cable.
- as. Locate EPA RE coupler interconnections for channel number recorded in step 1.al. and disconnect Coupler Cable W3 from Coupler DC2J2. Connect 25-foot cable to DC2J2.
- at. At RFM MS Maintenance Control Panel, set TRIGGER GENERATOR TRIGGER-MODE to FREE RUN.
- au. At REM A1 Control Panel, set TRANSMITTER PHASE/POWER MONITOR-CHANNEL selector thumbwheel to channel number recorded in step 1.ak.
- av. At RFM, locate ATI behind DAC (A13): adjust until PHASE/POWER meter reads 90 KW then tighten lock-tight.
- aw. At RFM, A15 Maintenance Control panel, set TRIGGER GENERATOR TRIGGER-MODE to SINGLE PULSE and set RF OSCILLATOR-POWER switch to OFF.

Next

Diagram | MRC Figure



Pilot Test Results

- Provide more advance organizers
- Conduct tests on non-alignment procedures
  - Alignments are the most difficult procedures
  - Trainees aren’t allowed to adjust alignments
- Develop content for procedures which guide troubleshooting, not alignment procedures

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Next Steps

- Create new Content
- Develop Tests
- New Measures

Creating New Content

- Eliciting knowledge from SMEs to create advance organizer content for finding faulty component

- Topics to address in constructing instruction:
  - Where are advance organizers inserted?
  - What is content of advance organizer?
  - How are graphics for advance organizers constructed?

Steps for creating advance organizers

- SMEs divide entire set of steps into meaningful groups/chunks
- For large chunks, SMEs provide
  - (a) process info,
  - (b) mental model
- Create easy-to-interpret graphic of mental models that guides trainee performance
- Construct Advance Organizers with
  - Prerequisites
  - Process & Functional diagram
  - Implications for later steps
- Review Advance Organizers with trainees

Dividing Steps into Chunks

4. Perform D/PD Phase Alignment (SPY-1D).

a. At each D/PD A1 Control Panel, press LOCAL/REMOTE switch and observe REMOTE indicator is lit.
b. Ensure Waveguide Switch Drivers T96 through T99 AC POWER-CB1 circuit breakers are set to ON.
c. At RFM A1 Control Panel, press RADIATE pushbutton and wait for transmitter to cycle to RADIATE. Ensure RADIATE indicator is lit.
d. Set TRANSMITTER PHASE/POWER MONITOR pushbutton to PHASE.
e. Set CHANNEL/SUM pushbutton to SUM.
f. Set appropriate RF SWITCH pushbuttons to connect D/PD T20 to FPA T26 and D/PD T21 to FPA T27.
g. Open RFM door and latch staybar.
h. Connect oscilloscope as follows:

NOTE 18 : Jacks located on RFM A19 Control Monitor are labeled from top to bottom, J10 (Power), J11 (SIN), J12 (COS).

(1) Connect channel 1 to RFM A19 Control Monitor J11 (SIN monitor output).
(2) Connect channel 2 to A19J12 (COS monitor output).
(3) Connect trigger input to Maintenance Panel A15CP1 (TRIGGER OUTPUT).

i. At RFM Z1 Phase Shifter, adjust Z1 until pulse waveform on oscilloscope channel 1 is nulled (no pulse present) and waveform on channel 2 is a positive pulse. This represents a zero degree phase shift.
j. At A15 Maintenance Control Panel, set RF OSCILLATOR - FREQUENCY knob to VARIABLE.
k. While observing PHASE/POWER meter on RFM A1 Control Panel, slowly adjust RF oscillator frequency through entire band and verify meter reads 0 ±30 degrees. Make adjustments to RFM Z1 as necessary to meet condition.
l. Record most negative and positive phase readings in table 2 (including D/PD combination and FPA Reference selected) while varying FREQUENCY ADJUST knob.

STEP	- D/PDs - Feeding T26/T27	Set FPA REF	PHASE SHIFTER to Adjust:	MOST NEG PHASE Reading	MOST POS PHASE Reading
4.l.	T20/T21	1-1	RFM Z1		

Table 2

m. Set RF OSCILLATOR - FREQUENCY knob to FIXED.
n. At A15 Maintenance Control Panel, set TRANSMITTER ALIGNMENT FPA REFERENCE switch to 1-2.
o. At D/PD T20, open right-hand cabinet door.

Dividing Steps into Chunks

4. Perform D/PD Phase Alignment (SPY-1D).

a. At each D/PD A1 Control Panel, press LOCAL/REMOTE switch and observe REMOTE indicator is lit.
b. Ensure Waveguide Switch Drivers T96 through T99 AC POWER-CB1 circuit breakers are set to ON.
c. At RFM A1 Control Panel, press RADIATE pushbutton and wait for transmitter to cycle to RADIATE. Ensure RADIATE indicator is lit.
d. Set TRANSMITTER PHASE/POWER MONITOR pushbutton to PHASE.
e. Set CHANNEL/SUM pushbutton to SUM.
f. Set appropriate RF SWITCH pushbuttons to connect D/PD T20 to FPA T26 and D/PD T21 to FPA T27.
g. Open RFM door and latch staybar.
h. Connect oscilloscope as follows:

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k. While observing PHASE/POWER meter on RFM A1 Control Panel, slowly adjust RF oscillator frequency through entire band and verify meter reads 0 ±30 degrees. Make adjustments to RFM Z1 as necessary to meet condition.
l. Record most negative and positive phase readings in table 2 (including D/PD combination and FPA Reference selected) while varying FREQUENCY ADJUST knob.

STEP	D/PDs Feeding T26/T27	Set FPA REF	PHASE SHIFTER to Adjust:	MOST NEG PHASE Reading	MOST POS PHASE Reading
4.l.	T20/T21	1-1	RFM Z1		

Table 2

m. Set RF OSCILLATOR - FREQUENCY knob to FIXED.
n. At A15 Maintenance Control Panel, set TRANSMITTER ALIGNMENT FPA REFERENCE switch to 1-2.
o. At D/PD T20, open right-hand cabinet door.

Dividing Steps into Chunks

4. Perform D/PD Phase Alignment (SPY-1D).

a. At each D/PD A1 Control Panel, press LOCAL/REMOTE switch and observe REMOTE indicator is lit.
b. Ensure Waveguide Switch Drivers T96 through T99 AC POWER-CB1 circuit breakers are set to ON.
c. At RFM A1 Control Panel, press RADIATE pushbutton and wait for transmitter to cycle to RADIATE. Ensure RADIATE indicator is lit.
d. Set TRANSMITTER PHASE/POWER MONITOR pushbutton to PHASE.
e. Set CHANNEL/SUM pushbutton to SUM.
f. Set appropriate RF SWITCH pushbuttons to connect D/PD T20 to FPA T26 and D/PD T21 to FPA T27.
g. Open RFM door and latch staybar.
h. Connect oscilloscope as follows:

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(3) Connect trigger input to Maintenance Panel A15CP1 (TRIGGER OUTPUT).

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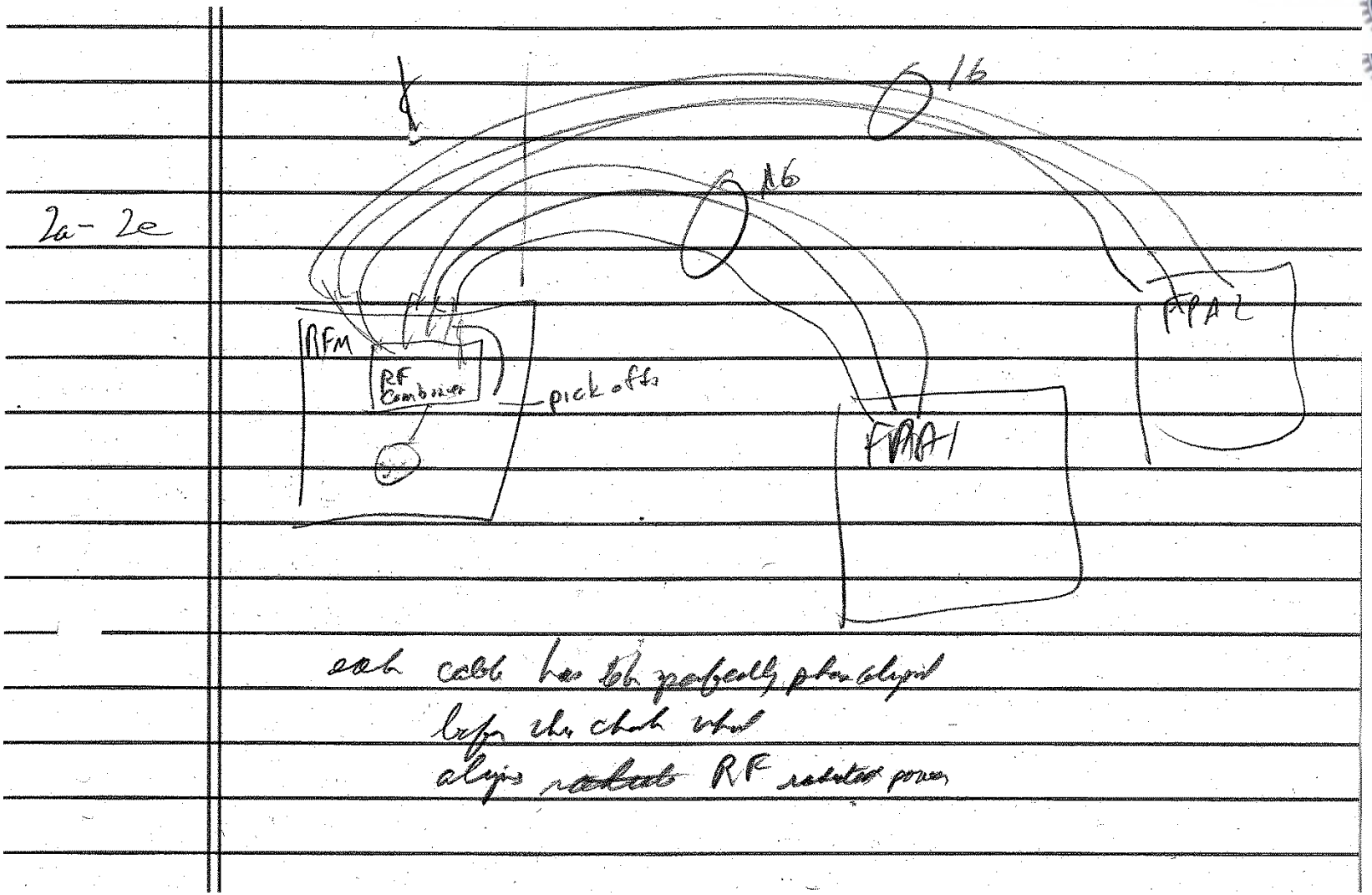
j. At A15 Maintenance Control Panel, set RF OSCILLATOR - FREQUENCY knob to VARIABLE.
k. While observing PHASE/POWER meter on RFM A1 Control Panel, slowly adjust RF oscillator frequency through entire band and verify meter reads 0 ±30 degrees. Make adjustments to RFM Z1 as necessary to meet condition.
l. Record most negative and positive phase readings in table 2 (including D/PD combination and FPA Reference selected) while varying FREQUENCY ADJUST knob.

STEP	D/PDs Feeding T26/T27	Set FPA REF	PHASE SHIFTER to Adjust:	MOST NEG PHASE Reading	MOST POS PHASE Reading
4.l.	T20/T21	1-1	RFM Z1		

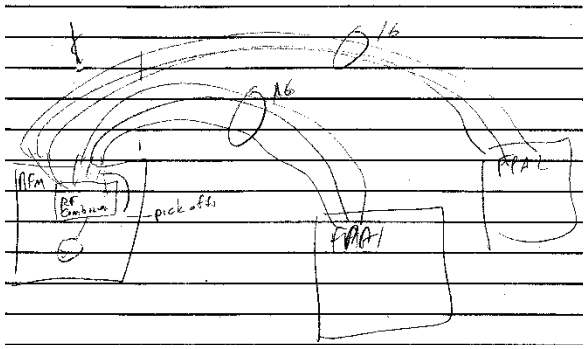
Table 2

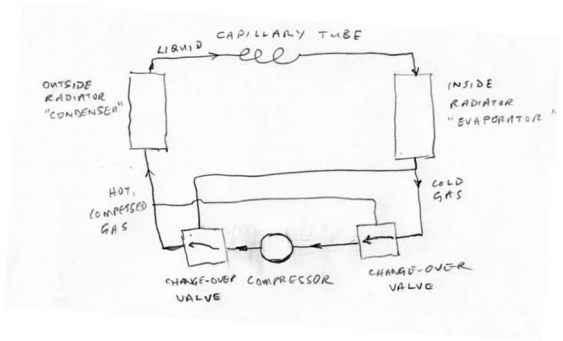
m. Set RF OSCILLATOR - FREQUENCY knob to FIXED.
n. At A15 Maintenance Control Panel, set TRANSMITTER ALIGNMENT FPA REFERENCE switch to 1-2.
o. At D/PD T20, open right-hand cabinet door.

Process Information and SME Mental Model

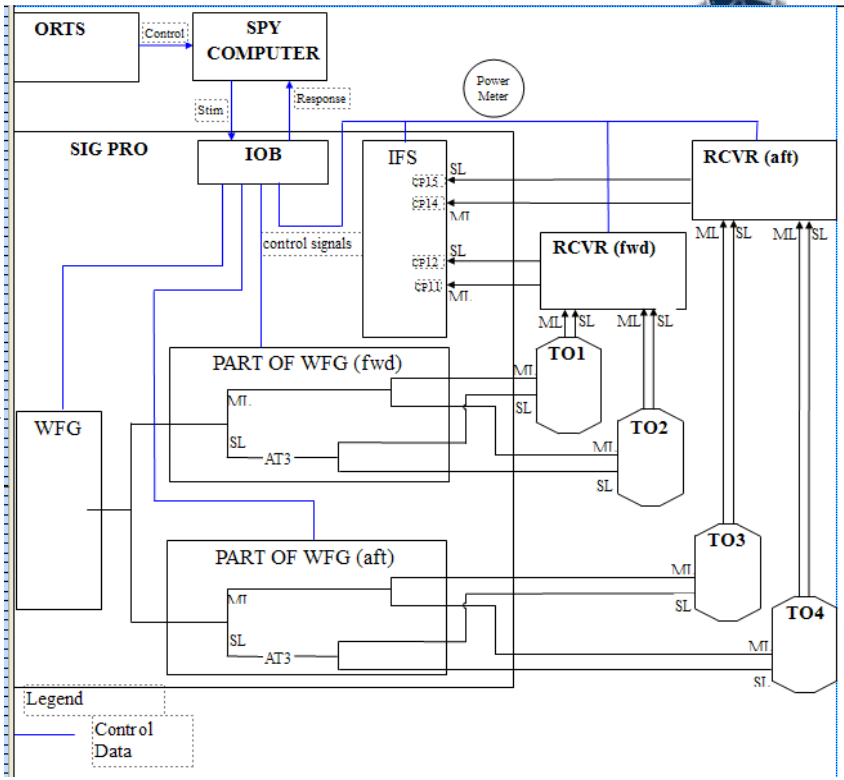


Integrate SME sketches into mental model

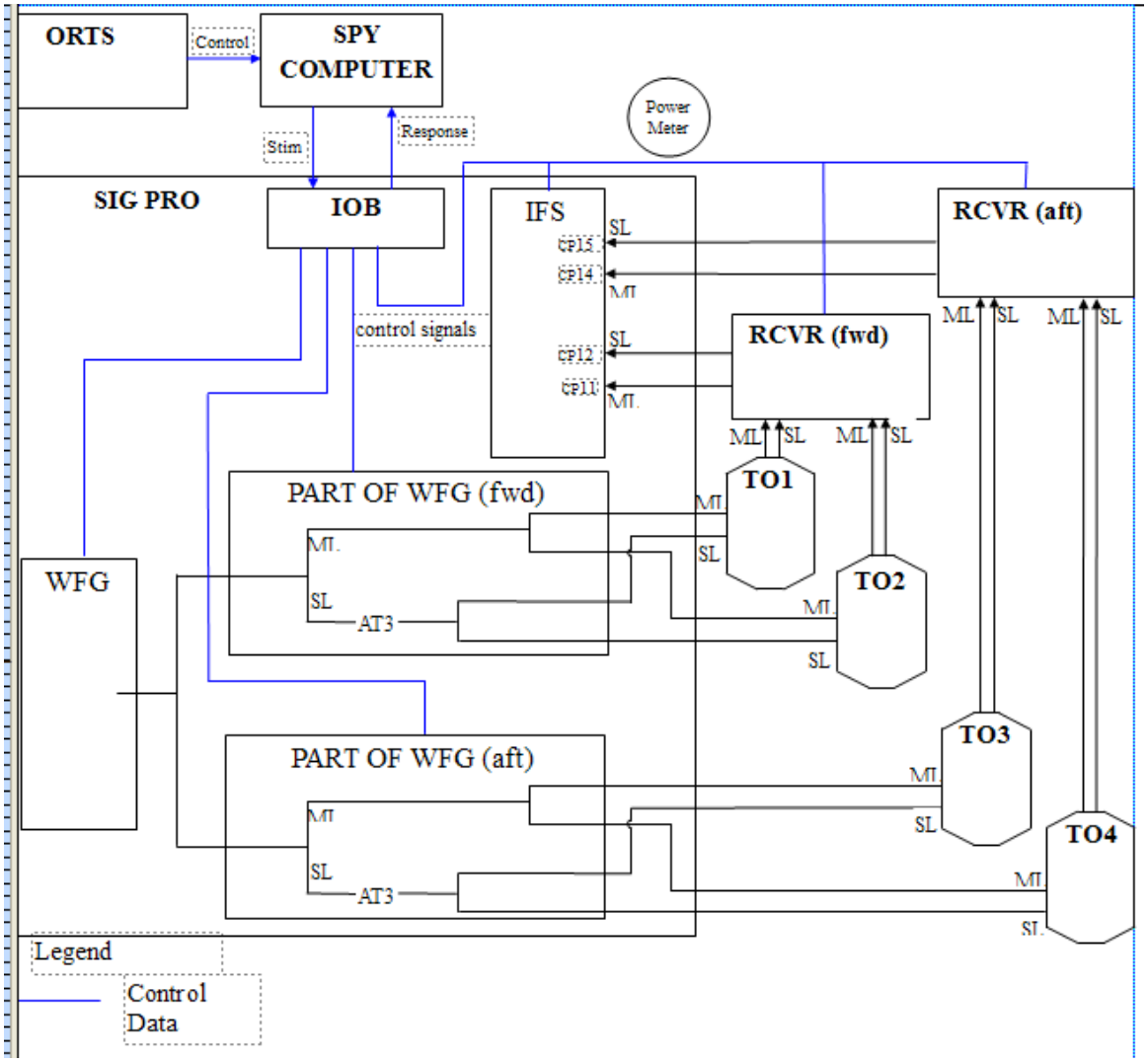




rules



Mental Model for a maintenance procedure



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Rules for creating mental model diagrams

- When drawing a diagram of equipment, we used a set of principles to keep diagrams clear:
  - Diagrams should include objects observed or manipulated (except when a component can be assumed due to familiarity, e.g., power input to a computer).
    - Identify all components mentioned in procedural steps.
    - Include all identified components in graphic.
  - Show direction of signal paths and data paths with arrows

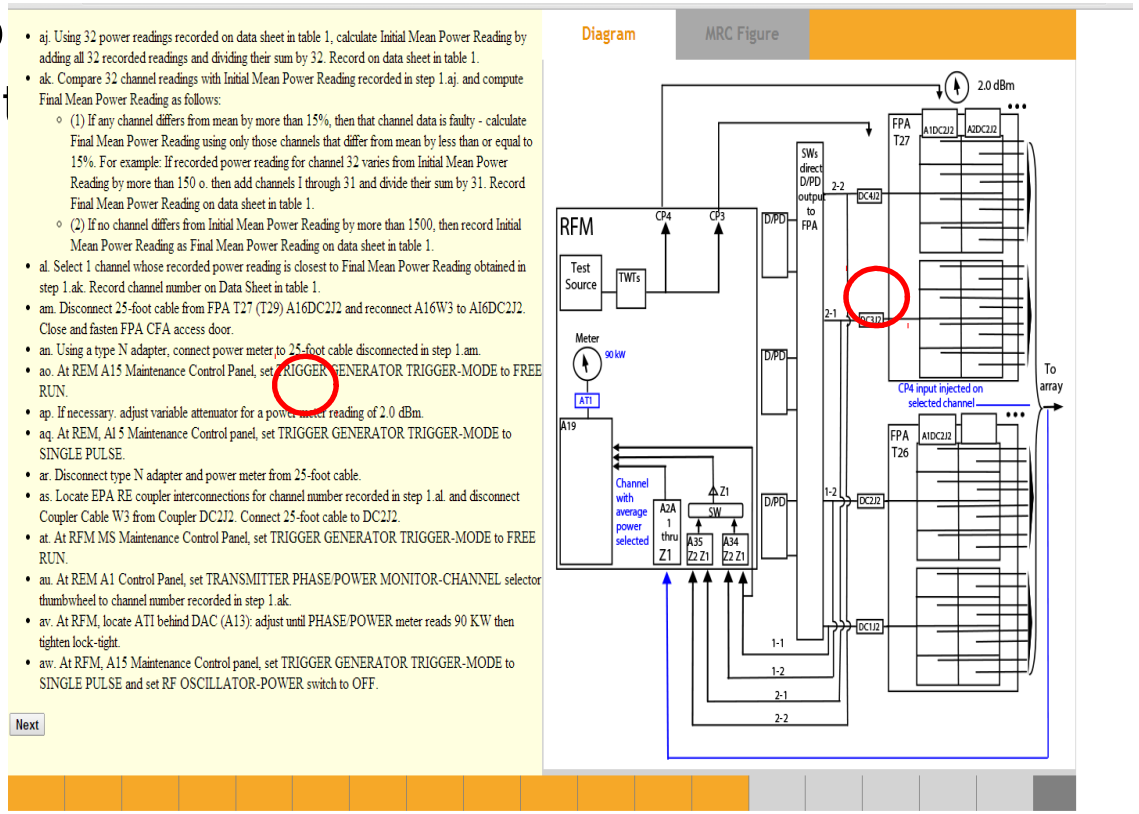
"Diagrams are absolutely perfect for new guys." (FC1 Chafin)

Testing Measures

- Knowledge pre-test (to create equivalent groups)
- Observations during task execution
  - Time to complete task
  - Number of faulty components correctly identified and replaced
  - Number of functional components incorrectly identified as faulty
  - Number of faulty components not identified
  - Any procedural steps incorrectly executed
- Knowledge post-test
- Compare performance of groups
- Questionnaire
  - Usability
  - Utility

Other potential measures

- Use eye tracking to examine where students are looking:
  - At procedural steps
  - At diagram o
  - At equipment


aj. Using 32 power readings recorded on data sheet in table 1, calculate Initial Mean Power Reading by adding all 32 recorded readings and dividing their sum by 32. Record on data sheet in table 1.
ak. Compare 32 channel readings with Initial Mean Power Reading recorded in step 1.aj. and compute Final Mean Power Reading as follows:
(1) If any channel differs from mean by more than 15%, then that channel data is faulty - calculate Final Mean Power Reading using only those channels that differ from mean by less than or equal to 15%. For example: If recorded power reading for channel 32 varies from Initial Mean Power Reading by more than 150 o. then add channels I through 31 and divide their sum by 31. Record Final Mean Power Reading on data sheet in table 1.
(2) If no channel differs from Initial Mean Power Reading by more than 1500, then record Initial Mean Power Reading as Final Mean Power Reading on data sheet in table 1.
al. Select 1 channel whose recorded power reading is closest to Final Mean Power Reading obtained in step 1.ak. Record channel number on Data Sheet in table 1.
am. Disconnect 25-foot cable from FPA T27 (T29) A16DC2J2 and reconnect A16W3 to AI6DC2J2. Close and fasten FPA CFA access door.
an. Using a type N adapter, connect power meter to 25-foot cable disconnected in step 1.am.
ao. At REM A15 Maintenance Control Panel, set TRIGGER GENERATOR TRIGGER-MODE to FREE RUN.
ap. If necessary. adjust variable attenuator for a power meter reading of 2.0 dBm.
aq. At REM, AI 5 Maintenance Control panel, set TRIGGER GENERATOR TRIGGER-MODE to SINGLE PULSE.
ar. Disconnect type N adapter and power meter from 25-foot cable.
as. Locate EPA RE coupler interconnections for channel number recorded in step 1.al. and disconnect Coupler Cable W3 from Coupler DC2J2. Connect 25-foot cable to DC2J2.
at. At RFM MS Maintenance Control Panel, set TRIGGER GENERATOR TRIGGER-MODE to FREE RUN.
au. At REM A1 Control Panel, set TRANSMITTER PHASE/POWER MONITOR-CHANNEL selector thumbwheel to channel number recorded in step 1.ak.
av. At RFM, locate ATI behind DAC (A13): adjust until PHASE/POWER meter reads 90 KW then tighten lock-tight.
aw. At RFM, A15 Maintenance Control panel, set TRIGGER GENERATOR TRIGGER-MODE to SINGLE PULSE and set RF OSCILLATOR-POWER switch to OFF.
Next
Diagram
MRC Figure
2.0 dBm
FPA T27
A1DC2J2
A2DC2J2
SWs direct D/PD output to FPA
RFM
CP4
CP3
D/PD
Test Source
TWTs
Meter
90 kW
ATI
A19
Channel with average power selected
A2A 1 thru Z1
Z1
SW
A35 Z2 Z1
A34 Z2 Z1
DC4J2
DC3J2
DC2J2
DC1J2
CP4 input injected on selected channel
To array
FPA T26
1-1
1-2
2-1
2-2

Summary: What we have addressed

- Improving performance in complex jobs
  - Mental Models presented
- Measurement of performance
- Knowledge elicitation
- Relationship of Performance Aids with Training
- Use of tablets for bringing information to technicians

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Discussion

- Very interested in receiving your comments and suggestions

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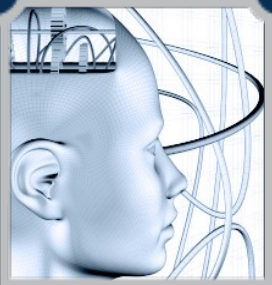
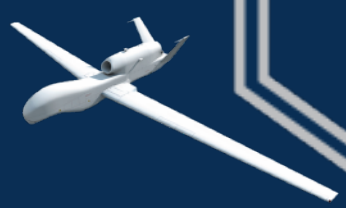
HFE TAG
May 19-22, 2014





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Discussion Question

- Would it be interesting to compare the Knowledge Elicitation method described above with more formal methods?
  - IDEF0
  - Functional Flow Block Diagrams
  - Concept maps

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